Asian J. Exp. Sci., Vol. 23, No. 1, 2009; 351-356

Thermal Effects of Mobile Phone on Tissue

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Abstract : The photons (electromagnetic waves) are scattered by tissues. After scattering the absorbed energy cases molecule vibration and the phonon created. In this paper interaction of photon with tissue has been verified. Assumed a photon interacts with tissue and creates a phonon. Therefore, transferred energy causes to increase temperature. Rising of temperature with photon frequency has been calculated and draw on a curve. In addition, number of photon interaction with tissue elements calculated in one cm^3, when incident power is 2W. The effects of incident power on absorbed energy and rising temperature have been depicted on the final section.

Key words : Mobile Phone, Non-ionizing, SAR, Photon, Phonon, Tissue.

PACS codes : 44.40.+a
44.90.+c

Introduction

Non-ionizing radiations (NIR) usually interact with tissue through the generation of heat. The hazards depend on the ability to penetrate the human body and the absorption characteristics of different tissues. Biological effects that resulted from heating of tissues by Radio Frequency (RF) and Macro Wave (MW) radiations are referred to as thermal effects. Generally the publications of NIR effects confirm the risks from RF and MW. Recently the world health organization (WHO) aids to raise awareness of the risks of NIRs (Florescu, 2007). Because of high conductivity of skin and muscle, the electric field does not penetrate deeply in to these tissues (Matthias Otto et al. 2007). But the magnetic field component of field penetrates deeply in to the body. A mobile phone transmits RF radiations in all directions and proportion of it is directed to the body. Recommended exposure limit for RF radiation from Mobile Phone is given in Table1 (Ng, 2003).

	Worker NRPB/ICNIRP	Public NRPB	Public ICNIRP
Whole body**	0.4	0.4	0.8
Head and trunk**	10	10	20
Limbs**	20	20	4

**SAR is a measure of the rate at which energy is absorbed by unit mass of tissue in an electromagnetic field. It is measured in the units of watts per kilogram (W kg-1).*
*** For calculating SAR the averaging time is taken to be 6 minutes for all tissues. ICNIRP also uses 6 minutes for the whole body but NRPB uses 15 minutes. The averaging mass is taken to be 10 g by ICNIRP while NRPB uses 10 g for the head (and fetus) but 100 g for the trunk, limbs and neck.*

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The ever-increasing rate of day-to-day use of radio and microwave EM waves causes to be studied the possible effects of these waves on tissues. Recent studies and investigations show that the direct effect of non-ionizing electromagnetic waves on human body is thermal effect. Their interaction with living tissues has more complicated associated aspects that if thoroughly understood may help to explain some of the unsolved important biological activities (Alhafid, 2005).

Non-ionizing energy loss can be discussed for the particles such as proton, neutron and photon (I. Jun. et. al, 2003). This paper concentrates on the non-ionizing effects of EM waves on human bodies.

Mechanisms of Photon interaction

RF fields induce torques on molecules and cause rotation and reorientation of them. Therefore exposures to EMF at frequencies above about 100 KHz lead to significant absorption of energy and temperature increases. The electromagnetic waves (photons) are scattered by tissues. After scattering the absorbed energy cases molecule vibration and the phonon created. We will assume that the tissue is made of an assembly of elements when electromagnetic radiation interacts with one of these elements. Most of the energy is elastically scattered. However, an extremely small part of the incident photons interact inelastically with the elements such as those phonons are created.

In our case we consider that a photon interacts with the elements of the proposed tissue and scatters on random direction. It is assumed a photon of initial frequency f_i is scattered by the element and its frequency becomes f_s. The rest of the energy, $h(f_i - f_s)$, is transformed to a phonon of frequency f. First we want to determine how much energy the tissue absorbs due to incident photon. We then relate amount of absorbed energy to temperature rise.

According to quantum mechanical theory, quantized energy stats given by equation (1) (Salem, 2005)

$$E_n = (n + \frac{1}{2})hf \qquad \text{......... (1)}$$

Where E_n is the energy of the n^{th} stationary states, n is an integer number that determines the energy level, or in other words the number of phonons and is the random frequency that les than f_i. Each element can only reside in one of those states. The f varies

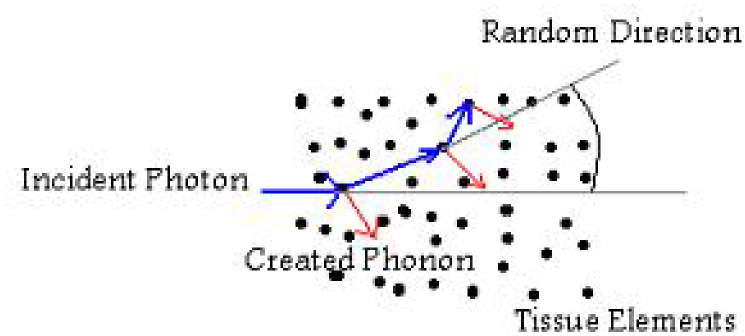

Fig. 1: The phonon is created by interactions of photon with elements

between zero and f_i. Therefore we used average f, $\frac{f_i}{2}$, on Equation (1)

$$E_n = nh\frac{f_i}{2} + \frac{1}{2}h\frac{f_i}{2} \quad \text{......... (2)}$$

It is clear that

$$hf_s = \frac{1}{2}h\frac{f_i}{2} \quad \text{......... (3)}$$

And the transformed energy to phonon is

$$\Delta E = nh\frac{f_i}{2} \quad \text{......... (4)}$$

By considering $n=1$, $\Delta E = \frac{1}{2}k_B\Delta T$ and $E_n = n - hf_i$ variations of ΔT with frequency has been obtained and showed on Fig.2.

Calculation of heating absorption on tissue

Mobile phones have to be designed in such a way that they do not exceed a Specific Absorption Rate (SAR) value of 2W/Kg. Recently, field exposure during mobile phone calls under every day conditions have been measured. The results were surprising: often enough the real exposure was higher then assumed before (Florescu, 2007).

Electromagnetic fields in the frequency range used by mobile phone and similar technologies do not penetrate deeply into the body. Most of the field energy is absorbed by the skin and the directly underlying tissue. This

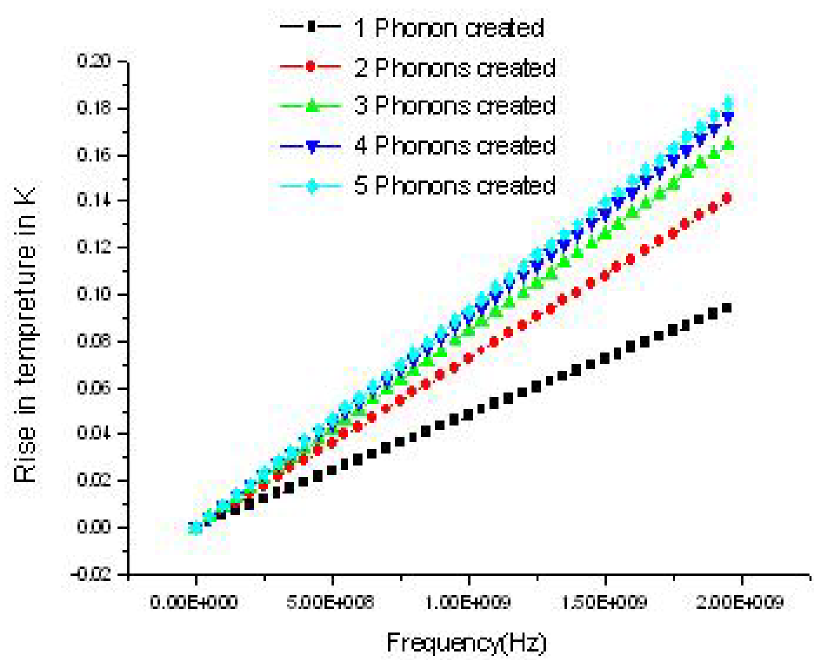

Fig. 2: Photons interact with tissue elements and create phonons. This figure shows temperature increases versus photon frequency.

is mostly due to the high electric conductivity of the skin. Heat generated in the tissue is mainly distributed by blood flow.

The parameter describing the amount of energy absorbed per unit of tissue within a given time is called the specific absorption rate (SAR unit: W/Kg) a SAR value of 4W/Kg would result in a temperature increase by 1°C.

Different antenna configurations can be programmed, that exhibit different photon mission characteristics. The user can also specify the wavelength of the sender and its power (A. Schmitz et al., 2006). A base station antenna typically radiates 60W and a handset radiates 1-2W (peak) (G. J. Hyland,200).

Heating of biological tissue is a consequence of microwave energy absorption by the tissue's water content. The amount of heating produced in a living organism depends primarily on the intensity (or power density) of the radiation once it has penetrated the system.

As seen on Fig.3., suppose that a stream of photons is incident on the sample, in that case the human head. The photons are a result of the electromagnetic waves emitted from the antenna of a mobile phone. The waves produced by the antenna have a spherical wave front. Assumed antenna is placed at a distance of 2cm from the head. Radiation intensity at a radius of 2cm is calculated by Eq.(5), where

is incident power.

$$I = \frac{P_0}{4\pi\ d^2} \qquad \text{......... (5)}$$

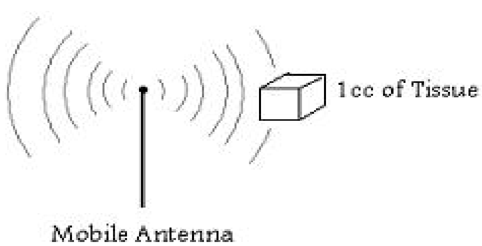

Fig. 3: One cm^3 of tissue receives photons from mobile antenna that located 2cm apart

The number of photons arrive on 1 cm^2 is calculated by Eq.(6).

$$n_{Ph} = \frac{I}{E_{Ph}} \qquad \text{......... (6)}$$

By considering cell density in tissue ($10^{12}\, cells/cm^3$) , cell radius is calculated by $r_{cell} = \frac{1}{2\times 10^4} cm$ (Fig.4).

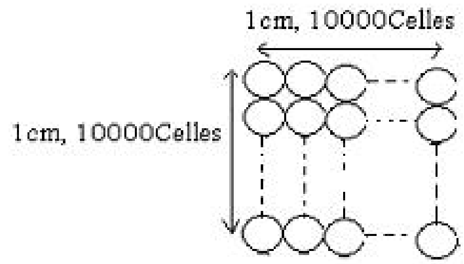

Fig. 4: By considering cell density in tissue (10^{12} cells/cm^3), the cell numbers on 1cm is equal 10^4

The infraction probability of a photon on P_0 1 cm^2 tissue is given by Eq.(7).

$$P_{In} = \frac{n_{cell}^2\ \pi\ r_{cell}{}^2 (cm^2)}{1(cm^2)} \qquad \text{......... (7)}$$

Number of photons interact with tissue cells ($N_{interaction}$) is equal $P_{In}.n_{Ph}$.

Variation of $N_{interaction}$ with frequency calculated and depicted on Fig.5. for $P_0 = 2W$. As seen on this figure, number of interactions with frequency increasing.

The heat transfer on 1 cm^3 tissue during a second is equal $P_{In}.n_{Ph}.H_{Ph}$, where H_{Ph} is proportional transferred energy of a photon. Fig.6. shows temperature rising and absorbed energy for different incident power.

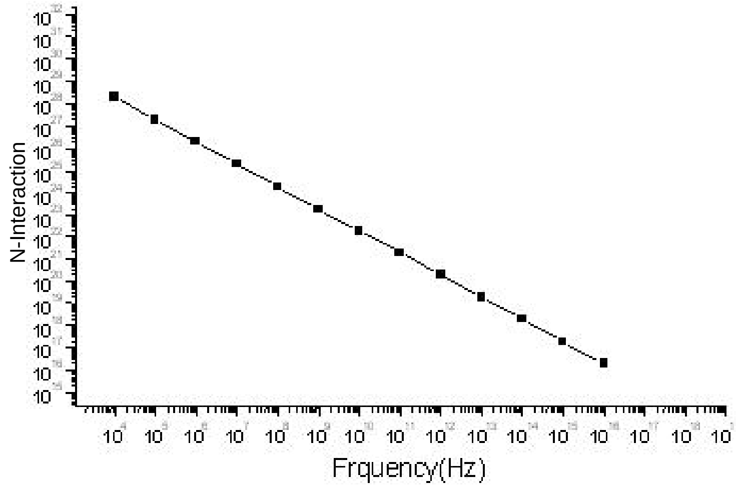

Fig. 5: For a incident power (2W), variation of photons ($N_{interaction}$) interactions with frequency

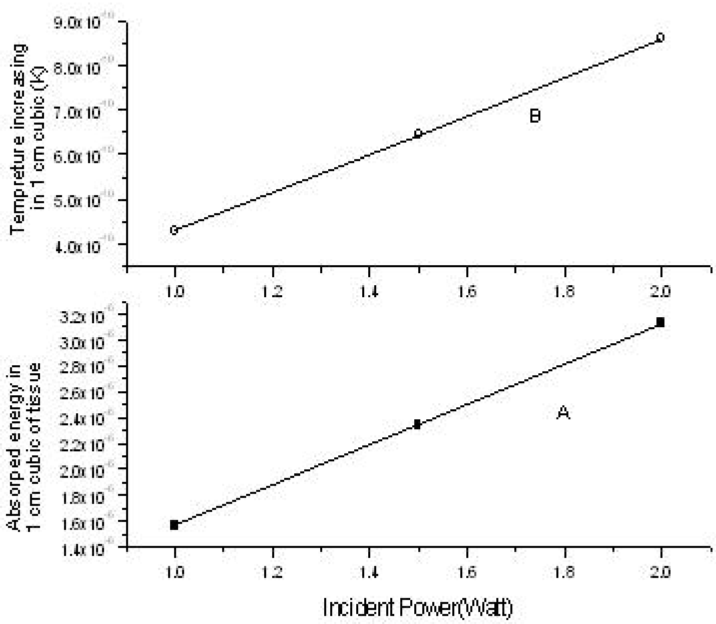

Fig. 6: Chang the increasing temperature and absorbed energy versus incident power

It is seen the incident power plays an important role on absorbed energy and rising temperature.

Conclusion

Electromagnetic fields in the frequency range used by mobile phone do not penetrate deeply into the body. Most of the field energy is absorbed by the skin and the directly underlying tissue. Their absorbed energy vibrates tissue elements and creates phonons. Phonons cause temperature raising that calculated by quantum mechanics theory. The obtained results show number of photon interactions decrease versus increasing of frequency. In addition, the incident power of mobile phones plays an important role on absorbed energy and raising temperature.

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